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INTEROCEANIC SHIP CANAL.

Special Meeting of the American Geographical Society, held at their rooms, on the evening of Monday, December 22, 1879.

Among others, there were present—Chief Justice Daly, the President of the Society, Mr. William H. Webb, Mr. John E. Body, General E. W. Serrell, Civil Engineer, Mr. Elial F. Hall, Mr. Octave Chanute, Mr. D. S. Moulton, Mr. Jess Young, F.R.G.S., Major Sidney F. Shelbourne, Mr. James M. Bowman, and Mr. Simon Stevens.

Upon calling the meeting to order, the President said that it was the intention to devote the evening to the consideration of the San Blas route for an isthmus canal, the last meeting having been given to the consideration of the Panama route, which led to the presentation of claims on behalf of opposing routes, among which was the San Blas.

The PRESIDENT said : Before the investigation commences, I think I should call the attention of those present to the fact that an address was made before the Committee on Technique, which, as I understand it, was the chief scientific committee of the Paris Congress, appointed to examine preliminarily the various routes, their advantages and disadvantages, by Mr. De Courcey, a civil engineer. The fact that he addressed such a committee is of itself an indication that he was a person of some consequence in their estimation ; and that his address was considered of importance, I infer from the fact that it has been translated and published in the last number of the *Popular Science Monthly* in this country.

I wish to call attention to three statements that he makes, one of which is certainly very extraordinary for a civil engineer professing to speak upon a subject with which he assumed to be acquainted—that is, to the effect (I give his language as in the translation) that to carry out the San Blas project a harbor must be built on the Atlantic. Now, it is known to geographers—at least, to all American geographers—that the bay of San Blas is a very remarkable one, and that in the northwestern portion of that bay, at the mouth of the Mandinga river, which is to be the mouth of the projected canal, there is a very fine harbor capable of accommodating vessels of any depth of draft. At least, that is the fact unless all the information we have hitherto received is unfounded, and Mr. De Courcey has information which we do not possess.

The other statement is, that at the mouth of the Bayano river, which is to be utilized for the canal on the Pacific side, and at the mouth or near the mouth of which the canal is to terminate—that on that side there is a bar which he says it is by no means certain can be mastered. He may be correct in this statement, for I am not particularly informed in regard to the mouth of the Bayano ; but there are gentlemen here who are, perhaps, informed upon that subject, and who can tell us whether there is such a bar, and whether the difficulties are so great as Mr. De Courcey suggests.

The last statement is in respect to the proposed tunnel on the San Blas route. He says that shipmasters do not take kindly to a tunnel with so long a passage without fresh air; that they will have an unconquerable antipathy to passing through it, even with the aid of an electric light. The passage through this tunnel as estimated, so far as I understand, will occupy about two hours—which amounts to the proposition that a shipmaster, from his " unconquerable " repugnance to a tunnel, would prefer carrying his ship around Cape Horn instead of going through a tunnel in a passage of two hours.

I mention these three facts, as they are reproduced in a publication here for the information of the American public, to show how, in my judgment, even in the most important committee of the Paris Congress, they were misled in respect to the true facts by gentlemen professing to have knowledge of them.

Major Shelbourne, who was heard on the previous evening in a criticism of Mr. Menocal's exposition of the Nicaragua route and its superior advantages, is here. If he is willing I will call upon him, and we shall be glad to hear from him as full an exposition of the San Blas route as he is disposed to make, giving us as far as he can an exact account of what is proposed to be done, the nature of the country through which it is proposed to pass, the character of this tunnel, and, so far as such a matter can be now judged of, its estimated cost, or any other matters which he deems essential in connection with it.

Major Sidney F. Shelbourne then came forward and spoke as follows :

ADDRESS OF MAJOR SIDNEY F. SHELBOURNE.

THE NICARAGUA ROUTE.

Major SHELBOURNE said : Mr. President and Gentlemen,—Before entering upon the principal subject of discussion for this evening, I beg your indulgence for a moment while I return to a detail of the Nicaragua route, which was under discussion at your last meeting, a week ago, and in which Mr. Menocal undertook to question a statement that I had made in reference to the breakwater or jetty, and the silt that would throw around it. His statement was to the effect that the jetty would be, as I understood him, some 600 feet long from the shore, and that it was intended to stop the drift of the sand along the coast, as it is now formed there, at the harbor of Greytown, and that eventually the condition would arrive in which the northeast trade winds, which now strike the present coast at an angle of 45 degrees, driving the sand along it, would fill up the angle to be formed by the breakwater with the coast so as to create a shoreline at right angles to the direction of the wind ; and thereafter the sand, instead of drifting westward in the direction of the proposed outlet for the canal, would be turned in another direction, and be driven towards the south.

I stated that the coast at that point trended almost, if not directly east, for a distance of between one and two miles. I had not made an exact measurement of the distance on the scale, and the question which Mr. Menocal put to me was as to the length of the coast trending directly eastward along which the sand would drive. Not wishing to speak at random, I said I would make a calculation, and at the next meeting of the Society I would present it.

Those of you who can see this portion of this map will see the direction of that coast. That point [referring to a location on the coast as delineated on Map No. 4, accompanying the report of the surveys of the Nicaraguan route by the United States government] is the proposed breakwater. It is not proposed to be built at right angles to the coast, but at an angle of about 115 degrees with the trend of the coast. I have produced here [exhibiting a diagram of the coast and an extended breakwater on a scale of one mile to the inch] a rough idea of the conditions which will obtain. This coast, from the place where the breakwater is proposed to be built out from it, trends directly east, as you see by the map, not a mile and three-quarters, as I stated, because I did not want to speak without exact knowledge, but I find, upon a calculation upon the plans and maps made by Mr. Menocal himself, that the direction of this coast eastward is for a distance of two miles and ninety-three one-hundredths from the point where the breakwater is proposed to be built. I stated that the sand driving along that coast would very soon fill up the angle between the shore and the end of the breakwater ; and then the breakwater would need to be continually extended in order to prevent the sand from drifting into the mouth of the canal. You will see, then, since the northeast trade winds strike this three miles of coast at an angle of 45 degrees, the conditions for turning the sand in another direction, which Mr. Menocal hopes to attain, will not arise in Greytown harbor until this breakwater is extended out a distance equal to the distance from the shore end of the breakwater to the point eastward where the coast faces off towards the sonth, which is about three miles.

The length of the breakwater, as it is proposed to be built, if I understood Mr. Menocal's statement correctly, would be represented on this diagram of a scale of one inch to the mile, by a line only one-eighth of an inch in length. But the condition of safety for the canal would not be attained until the breakwater actually built could be represented on this same scale by a line nearly three inches in length, so that when the breakwater shall have been extended for a distance of three miles from the shore, and the angle formed by it with the three miles of coast should become filled up with sand, the wind would then drive the waves bearing the sand at right angles to the new-made shore, and the movement westward would probably cease and possibly the sand find an easier lodgment in another direction. Now, 600 feet is a little less than one-eighth of a mile ; consequently, if the breakwater is to be 600 feet long at the commencement, it would have to be extended twenty-four times its whole length before the condition of security would arise. The danger of the sand drifting into the mouth of this canal around the breakwater, and its rapidity of lodgment, will be apparent to you when I repeat Mr. Menocal's own statement that a half million of cubic yards of sand and debris is brought down by the San Juan river and fed to the waves of the sea through its outlets at and near the harbor of Greytown—a half million cubic yards every year.

Mr. Menocal has said that all engineers who have examined his plans for a breakwater here at Greytown have approved of them, and that they were approved by the Paris Congress. I think you all will approve of this proposed breakwater as a makeshift for the present, and as the beginning of a very prolonged struggle with a herculean difficulty. However, Mr. Menocal himself states that it will need to be extended from time to time. In that statement he admits the whole objection. I should approve of it, too, if the Nicaragua route were the only canal route, and every engineer can see that to build a breakwater or jetty at right angles to a coast along which the sand is driven, will stop the sand for a certain length of time.

THE SAN BLAS ROUTE.

Turning from the subject of the Nicaragua canal to that of the route by way of San Blas, I have to say, in the first place, that every feasible and available route except San Blas, every route that is now brought to the public ear, has had its government surveyor and its official volume, containing very extensive letterpress and numerous detailed maps; but the San Blas route has nothing to represent it that the government did or paid for, except two small maps among seventeen contained in Commander Selfridge's report, the letterpress of which, relating to the San Blas route, is comprised in six pages.

It was the great misfortune of the San Blas route that a private citizen spent his money and sent his engineers down to the isthmus some six or seven years before the first of the prominent government surveys were made, and the fact that he thus surveyed this route, and made his map of it, and advocated it, so that it was called the "Kelley route," was enough to condemn it in the eyes of the government officials. A naval officer does not take his cue from a civilian, nor, if he can help himself, does he propose to take a secondary place in any project, scheme or exploration that a civilian has commenced and carried to a certain progress of demonstration. Therefore the naval officers—each one who made a survey upon the isthmus—had routes of their own, and Selfridge, who merely went to the Gulf of San Blas after the beginning of the rainy season, and spent a few days there and made a reconnoissance up the mountain, following the crooked beds of the watercourses and a partial and tortuous chain and level survey upon the ridge, in his report elaborates a route that his own name could lead, the Atrato Napipi route, and the great bulk of his maps are devoted to the detailed plans of that route, commencing in the Gulf of Uraba, and ascending the Atrato river for 150 miles, and reaching the divide in the general line of the valley of the Napipi with a tunnel through the ridge, and with locks down to Cupica or Limon bay on the Pacific. The Tehuantepec route, surveyed under Captain Shufeldt, has its volume bound in red, perhaps because it is a demonstrative color. The Nicaragua route has its volume, the final survey being made under Commander Lull. The Panama route has its volume, and, as I have just said, the Atrato Napipi route dwarfs everything else in the voluminous theme of Commander Selfridge. I will not, however, undertake to explain how it happens that each naval officer has come to have his judgment invariably set in favor of that route the report of which bears his own name in large capitals on its title-pages. It is, undoubtedly, natural that a father should love his child, and wish, too, to be publicly recognized as the father of his own.

But if the officers of the United States government have failed to give to the San Blas route that attention which it deserves, and if it is not represented before you to-night by a detailed report of a government officer and by maps of profiles and sections, and plans and minute details, elaborated at Washington, it may fortunately be said that nature herself has presented her strongest arguments for the San Blas route, and the geographer, true to her, as he hopes to declare the merits of his work, has delineated them in every school atlas, and they may be found upon the shelves of every scientific society. It is enough to say that it has long been shown in all atlases that at San Blas the isthmus comes to its very narrowest—less than 27 minutes of a degree of latitude—as Mr. Sweet makes it, and Mr. McDougal's survey, 30 miles and a small fraction. Commander Selfridge, however, represents it in his report as being 37 miles from ocean to ocean. How he arrives at this length I cannot imagine, while on his map, according to the scale, the whole direct distance across from ocean to ocean is a trifle under 30 miles. As this latter distance agrees, within a few feet, with the results of McDougal's survey, it should be assumed to be substantially correct. If Commander Selfridge had taken the trouble to determine the true latitude and longitude of the shore on the Pacific side at the mouth of the Bayano river, we could have known the exact distance across the isthmus at this point to within at least 150 feet. None of these maps which are hanging on the wall before you will show the direction to the Gulf of San Blas from New York ; but bearing in mind that the longitude of New York and the eastern point of Cuba is about the same, being 74° west from Greenwich, the route as far as Cuba will be in a great circle, and taking what is called the windward channel, we pass the eastern extremity of Cuba, and then bearing southwest by south, we also pass the eastern point of the island of Jamaica, striking the Gulf of San Blas on a direct course, and passing Point San Blas on a southwest by west course, we enter the magnificent harbor of Mandinga. Now, the distance from New York by the passage I have delineated to the proposed San Blas canal is 85 miles less than that by the same windward channel to Greytown, the Atlantic terminus of the proposed canal through Nicaragua. We will commence with the exposition of the San Blas route on the Atlantic side, while on the Nicaragua route they have usually commenced on the Pacific side. We reach, then, across this open sea, the Gulf of San Blas, as represented upon this map [referring to Mr. Kelley's map of the San Blas survey loaned to the society], and 85 miles nearer to New York, as I have said, than Greytown. This map was made by Mr. Sweet, one of Mr. Kelley's engineers engaged in the survey. This survey was made in 1864, under the auspices of Mr. Kelley and Mr. Cyrus Butler, and no complete survey of this route has ever been made since, but only a reconnoissance and partial survey by Commander Selfridge in the expedition of 1870. The engineers of Mr. Kelley commenced their survey upon the Pacific side. Pausing here, I will say that this harbor of Mandinga was surveyed by Commander Lull, then under Selfridge, but afterwards having command of the expedition which completed the survey of the Nicaragua route. It was commenced in April, 1870, and was completed during the time of the land survey of the San Blas route under the other officers of Commander Selfridge's expedition of that year. Lull spent twenty-five days altogether in the survey of the approach to this harbor, and in a trigonometrical survey of the harbor itself and the Gulf of San Blas. There is an area here in the harbor of as much as nine square miles, where a vessel can ride at anchor at all times with perfect safety. As you approach this harbor from the Gulf of San Blas through the channel which has been named after Admiral Porter, and pass the southernmost of an extended parallel group of islands which form its northeast boundary, the depth of the water in the harbor is 112 feet and as you pass inward towards the delta between the mouths of the Rio Mandinga, you have a depth of 30 feet within 300 yards of the shore. The bottom of this harbor is a clay and clayish mud, so you see it affords an excellent holding ground. The mouths of the Mandinga river are not shown upon Mr. Kelley's maps, except one of them, as you will see here by this slight shore indication, which was perhaps plotted afterwards from Commander Lull's survey of the harbor. The river Mandinga has two mouths opening into this harbor of the same name. The reason that Mr. Kelley's engineers have not located the mouths of the rivers Mandinga, Vercalagua and Carti, which open here into the gulf of San Blas, is that at the time their survey was made in 1864 this tribe of Indians inhabiting the Atlantic slope of the Cordilleras at San Blas had been almost entirely excluded from contact with civilization, and were very hostile. They were very jealous of the presence of strangers, and when Mr. Kelley's party of engineers and surveyors got over the ridge down to the low land—for about three miles the ground does not rise more than four or five feet above the sea level, and during the rainy season it is a part of the time overflowed—when they got down here the Indians made hostile demonstrations, and the surveyors were obliged to get back over the mountain.

I have here a small map, which Mr. Curren has kindly pinned up for me, which was made under the auspices of Commander Selfridge, and is map No. 12, accompanying the report of his expedition of 1870. It will show you the chief features of at least the Atlantic division of the San Blas route, and the details of Mandinga harbor and the Gulf of San Blas, for it was to these features, not examined by Mr. Kelley's engineers, that the most of his attention was directed. As this map is very poorly plotted, and as the lines are not in colors and not very prominent, it will be very difficult for those of you in the back of the room to see the details of this Gulf of San Blas. At any rate, I can explain to you that Point San Blas, shown on this map, is the point of the mainland the furthest towards the northeast of this whole region of the isthmus lying to the south, southeast of Aspinwall, and that it forms the northern shore of the large Gulf of San Blas, enclosed between it and the mainland, at the mouth of the river Carti on the south. The entrance to the Gulf of San Blas is from the direction of northeast by east. There are a number of outlying islands here, which protect the gulf and the interior harbor of Mandinga, and make it safe at all times. The entrance, however, into the interior harbor is by a broad channel, called, as I have indicated, Porter channel.

This Mandinga harbor, then, embracing an area of about nine square miles, is intended to be the Atlantic terminus of the San Blas interoceanic canal.

The two mouths of the Rio Mandinga are separated from each other by a distance of two and a half miles, while it is only one and a half miles in a direct line across the delta from the shore to the point where the river separates into its two outlets. Altogether, for a distance of three miles in a direct line from the harbor shore, the Mandinga passes through low ground, scarcely elevated above the sea, and then we begin to find rising ground as we ascend in its bed. If we were standing upon the slope of the Cordillera to the southwest, and looking towards Mandinga harbor and the Gulf of San Blas, and the dense verdure and intervening ridges did not obstruct the vision, we would see the Mandinga river on our left entering into the harbor towards the east; the Rio Vercalagua before us, and partly to the right, also entering into Mandinga harbor, further towards the right and in a northerly direction; and on the extreme right the Carti river entering into the Gulf of San Blas, in a northerly direction, near the easterly limits of the southern shore of the gulf next to the sea.

As the Rio Mandinga is quite to the left, and the Rio Carti far to the right of the proposed line of the canal, their peculiarities and water-shed do not enter into the problem before us, although both of these rivers find their source far up towards the centre of the isthmus. But the Vercalagua more directly interests us, because through a portion of its upper valley would the open cutting of the canal on this side of the Cordillera be made. It has its rise on the Atlantic slope of the Cordillera, about seven miles in a direct line from the harbor of Mandinga, and when you get three or four miles from the harbor, and strike its valley, it is nothing but a little mountain rivulet, sometimes dry, but in the wet season a little mountain torrent. The open cutting of the canal would strike the bed of this river at a distance of two miles from the point where the canal begins, at the harbor of Mandinga, and follow its bed in general direction for another half mile, when it again leaves its bed, and takes the valley to the right or southward of the stream itself, to the point where the tunnel would commence, five miles from the harbor of Mandinga. It will be seen, therefore, that the Vercalagua will have a new direction or debouchement given to it from a point two miles and a half from the harbor of Mandinga, by the embankment of the rock debris brought from the tunnel, and that its outlet into the harbor will then be near the southernmost mouth of the Rio Mandinga.

I will now go forward and locate for you the termini of the proposed San Blas canal, and give you the approximate length and character of its sections. Its Atlantic end would be in latitude 9° 26′ 56″ north and longitude 79° 2′ 50″ west, the harbor of Mandinga presenting at this point the nearest available approach southward towards the ridge of the Cordilleras. This end of the canal may be further located on the map by a distance of 2 miles 550 yards in a direction west by southwest from the mouth of the Rio Vercalagua. The first section would be five miles of open cutting in a generally south southwest direction. Then would follow the tunnel for a distance of seven miles through the Cordillera, varying but little in direction from a meridian of longitude, and terminating upon the Pacific slope of the range about a half mile east by northeast of the falls of Salto. From this point the canal would be led by an open cutting a distance of 12 miles into the Rio Bayano at its great bend, a point six miles from the Bay of Panama. And now returning to the Atlantic side, let us follow this work more in detail. The five miles of open cutting commencing at Mandinga harbor would pass for a distance of two miles through a lowland, which lowland is not a mud—not a soft mud—since it is composed of a reddish yellow clay in the main part, with some vegetable decomposition and dark alluvium upon the surface.

For nearly three miles the cutting would be quite light. I may say in this connection that the tide passes up this river, the Vercalagua, for a mile and a half, and the tide only rises and falls on an average eight-tenths of a foot in the harbor of Mandinga, so that you can see how little the rise of the ground must be for that distance, since eight-tenths of a foot brings the tide a mile and a half up that river. After you get three miles in a direct line from the harbor of Mandinga, the ground begins to rise rapidly until, at a point five miles from the harbor, you come to an elevation 190 feet above the surface of the sea.

It has been laid down, and seems to have been agreed to by engineers generally, and by persons who have studied this subject, since no one has presented adverse views, that when you arrive at a depth in open cutting of 190 feet above the sea that it would be cheaper and more desirable to make a tunnel. If this depth of open cutting, therefore, be taken as the proper one for commencing the tunnel, the length of the cutting of this depth would not be more than a quarter of a mile in the situation under our consideration, for the surface of the ground immediately falls down to an elevation of 166 feet, then to 130, 98 and 66 feet at the middle point of this five miles of open cutting, while the average of the remainder is but a trifle above the sea. It is to be observed, however, that when we add 28 feet, the depth of the canal below the sea level, to the 190 feet of open cutting above that level, we will have, for a few rods of open cutting just at the mouth of the tunnel, a depth of 218 feet, and the tunnel being proposed of a height of 168 feet above the bottom of the canal, it will be seen that there will remain above the arch of the tunnel at its commencement a roof of rock of a depth of 50 feet.

Two routes for the tunnel suggest themselves to those who have studied the features of this portion of the isthmus, slightly varying from each other in their outlet on the Pacific side; but which would be the most advantageous would depend upon more accurate surveys.

There have been a great many fears expressed, and a great many doubts entertained in regard to the feasibility of the tunnel—in regard to its cost—in regard to its utility after its construction, and in regard to the stability of its natural arch, involving the question of the probable necessity for supplying a masonry arch for the whole length of its seven miles.

Judge DALY: And the danger of the inflow of water?

Mr. SHELBOURNE: Yes, that is one of the expected difficulties—the infiltration of water through the rock into the tunnel while it is being excavated the 28 feet below the surface of the sea.

I wish, however, first to speak of the problem of the length of this tunnel. There is a wide discrepancy between the two surveys, or partial surveys, as we must call one of them, in regard to the distance through the Cordillera at an elevation of 190 feet above the ocean, and consequently in regard to the probable length of the tunnel. It will be worth the time to explain how that arose.

If you will follow the direction of the river Bayano, on this map of Mr. Kelley, up from its mouth at the Bay of Panama to the junction of the river Mamoni, and then up that river to the dividing ridge and over it, you will trace the principal line of survey made by Mr. Kelley's engineers. Commencing in the Bay of Panama, they made an accurate survey up the Bayano and the Mamoni, locating all the bends, banks, spurs of hills and points of shore, and passing in the same way up the Mamoni, skirting a spur or ridge of hills on their right, which approaches from the east close to the Mamoni, they came up that river to the falls of Salto, in the first range of the Cordillera on that side through which the tunnel would have to be made. Knowing the general direction of the proposed tunnel to be north from the point where they were, they took the bend of this first range of the Cordillera, and found, instead of its being directly east and west, that it fell away toward a point north of east on their right; they therefore surveyed along the foot of this range towards their right for something more than half a mile, and located the Pacific end of the tunnel, as they thought, in the most favorable and advanced position northward to be found in the base of the mountain. Returning to the Mamoni, they continued a chain and level survey up the circuitous valley of this river, noting every angle with their instruments, and coming to the sources of the Butler river, a north and south branch of the Mamoni, they passed over the divide, and finding the head-waters of a branch of the Samgandi, they passed down the Samgandi and the Mandinga, with which it joins, to the base of the Cordillera on the Atlantic side, where, as I have said, they were driven back by the Indians. Now, as far as the mountain itself is concerned, this survey of Mr.

Kelley's engineers, although it was a series of circuitous valleys, was, nevertheless, unique and complete, and the determination, upon a scale, of the consecutive series of angles obtained, will give us the distance in a straight line from one side of the mountain to the other. That they did not go from the base of the mountain on this Atlantic side to the harbor of Mandinga, here shown on Selfridge's map, and obtain the exact distance, and locate the mouths of the rivers which flow into the harbor and gulf, and get the topography of the harbor and the bearings of this point of San Blas and all the locations hereabouts, does not make any difference as regards their survey of the ridge of the mountain.

You see that this map [referring to map 12 of Selfridge's report], so far as the Pacific side is concerned, was made entirely from Mr. Kelly's survey. Here is almost, if not quite, a complete copy, on a reduced scale, it is true, of the curves and bends and direction, and everything else, of this river Bayano. Nobody made a proper survey of this side of the isthmus for this route, except Mr. Kelley's engineers, that I am aware of. Mr. Kelley's engineers passed over this ridge entirely. Mr. Selfridge's engineers, when they made their survey six years later, commenced on the Atlantic side in the harbor of Mandinga, and passed up the valley of the Mandinga river and its branches, in the same circuitous way in which Mr. Kelley's engineers came down, until they passed over the ridge, and came to the junction of the river San Jose with the Mamoni, where they fixed upon the marks of Mr. Kelley's survey, and joined their line with his. Commander Selfridge says, in his report, that they met Mr. Kelley's survey at the junction of that river, San Jose, with the Mamoni, and that they found there only half a mile of difference or variation between the location of that point, as determined by his own surveyors and the surveyors of Mr. Kelley. And he says further, that this half mile of variation shows the accurate work of Mr. Kelley's engineers, for they took their base line from the coast line of the Pacific, while his own party took their line from astronomical observations; and he says of the Pacific shore line, that it "is doubtless half a mile in error." Now, Mr. Selfridge's surveyors, in plotting this map [No. 12, before referred to], went to work to join their survey to Mr. Kelley's surveys, and they brought out this sheet accordingly. It is a hybrid production, part of one sort and part of another; and in the merging together of two surveys it may be readily understood how, when they plotted their map, they could make upon it the distance through this mountain here, in a direct line, to show ten miles or any other imaginable approximation. That there is an error in this map [No. 12] is apparent, for this reason. You will observe the direction of that ridge of the Cordillera [the first extended ridge on the Pacific side on which are located the falls of Salto]. As it has been plotted on this map [No. 12] it is almost at right angles, if not at right angles, to the proposed direction of the tunnel. Upon the general map of the Isthmus of Darien [map No. 1, accompanying Selfridge's report], that range of mountain immediately to the eastward of Salto falls turns to the northeast until it meets the longer range bearing south of east. By measuring the distance from a fixed point on the Bayano river, on the scale of Selfridge's map, to the points of this range of the Cordillera, as shown on the map, and comparing these distances with the same distances as determined on the scale of Mr. Kelley's map, from which the other was made, an error appears in Commander Selfridge's map, in a single particular alone, of one and one-half miles. I compared the distance and pointed out the error to General Newton, who seemed to agree with me that the method of detection was conclusive.

Another point is this : In determining the length of the tunnel through this mountain to be ten miles, Commander Selfridge took his starting point on the Atlantic side from the valley of the Mandinga and his elevation above the sea at 160 feet, counting 30 feet for the bottom of the tunnel below the sea level to make up the 190 feet for his tunnel starting point. Now, the valley of the Mandinga, looking down the Atlantic slope, is quite to the left and decidedly away from the direct and shortest cut through the mountain, and his elevation of 160 feet in the Mandinga valley is much to the rear of the point adjacent to the valley of the Vercalagua, where the tunnel would commence.

A further indication is worthy of notice. A member of the party which surveyed the Rio Vercalagua, states in his report that the mouth of this river has a direct south bearing from the point of San Blas, while in fact it is located on Commander Selfridge's map nearly four miles to the westward of that bearing. If the reporting officer had made that statement of the mouth of the Rio Carti, either the map or the officer would have come within two-thirds of a mile of the truth. These various particulars, then, show that this map of Commander Selfridge, being plotted by the surveyors who made a partial survey and appropriated Mr. Kelley's surveys for the rest and filled up a gap of half a mile at the point of junction, is altogether unreliable as to the distance through this mountain and the length of this tunnel; while Mr. Sweet, who has in his notebook every particular of his work over this whole ridge, since this question came to be talked about and since the sitting of the Paris Congress, has gone over the details of his map and the length of this tunnel, and he cannot find any error in it. So that it may be taken for granted, upon all the best information that we have at present, that this tunnel will not be more than seven miles long.

Judge DALY : At what point of elevation do you place the commencement of this tunnel ? I ask the question for this reason : If I correctly recollect, Commander Selfridge in his report states that the tunnel will have to commence at about 350 feet of elevation, assuming that he makes the distance ten miles.

Mr. SHELBOURNE : 190 feet above the sea is assumed as the elevation for commencing the tunnel. I am not aware that Commander Selfridge so spoke of the San Blas route. I cannot find any such statement in the text of his report. He speaks, however, in a supplement to his report, of a possible lock canal on this route, with thirty-one locks, to gain an elevation of 372 feet, and then a tunnel of seven miles through the ridge. It may be, though, that he has made some such statement as you name of the Napipi.

Judge DALY : I think not. I will send for the report.

Mr. SHELBOURNE : We then have the length of the tunnel, as far as we are now able to determine it.

I want now to advert to the method which was very feasible to Commander Selfridge, with the facilities at his command, for determining the length of this tunnel astronomically. You will observe that the direction of the tunnel is almost exactly upon a meridian of longitude; that is, the question of longitude, for determining the length of the tunnel astronomically, does not come into the problem. Conceiving that such a simple method of determining the length of that tunnel would be feasible, I wrote to the Naval Observatory at Washington, and I have a letter from Rear Admiral Rodgers, which, with your permission, I will read :

U. S. NAVAL OBSERVATORY,
WASHINGTON, *September* 9, 1879.

Dear Sir: It is difficult to answer your question, since the skill of the observer is so important an element ; but in a night a zenith telescope may, in good hands, be put up and a result obtained for the station, with a no greater probable error in latitude than the quarter of a second.

With this error assumed for each end of the line, the probable error in the length of the tunnel, supposing that the stations are upon the same meridian, will be found by this formula:

$$\pm \sqrt{(0''.25)^2 + (0''.25)^2} = \pm 0''.35.$$

This represents a probable error of some 36 feet.

Yours very respectfully,
JOHN RODGERS,
Rear Admiral, Superintendent.

I also wrote to Professor Peters, of the Litchfield Observatory at Clinton, and he writes:

LITCHFIELD OBSERVATORY OF HAMILTON COLLEGE,
CLINTON, N. Y., *September* 16, 1879.

SIDNEY F. SHELBOURNE, Esq.

Dear Sir: An experienced observer, with suitable instruments, should be able to determine the latitude of a place by one night's work to within one or two seconds of arc, that is, about to within 100 or 200 feet.

Yours respectfully,
C. H. F. PETERS.

Both of these eminent gentlemen agree, then, that with such a telescope as Selfridge had at his command, his parties might have placed their station of observation at an elevation of 190 feet up the Rio Vercalagua on the Atlantic side from the harbor of Mandinga, and in one night made an observation; and upon the Pacific side at an elevation of 190 feet, and in one night made an observation, which would have determined within at least 200 feet the length of this tunnel, and settled this question upon the basis of fact, and not upon that of conjecture. But these observations were not made, and while the party attached to Commander Selfridge's survey had an astronomical station upon the shore of the harbor of Mandinga and determined its position, we have no account of any observations made anywhere on the interior of this route or on its Pacific side. It was Lieutenant-Commander Eastman who made a hydrographic survey of the Bayano river on the Pacific side; and in regard to the point that Judge Daly mentioned at the opening of this meeting, as coming from a statement made by a member of the Paris Congress before the Committee on Technique, that an insurmountable bar existed at the mouth of the Bayano, I will say that the report of the officer making the survey says that a bar had been located there by all the charts with not more than six feet of water on it, but that he found no such bar; but, on the contrary, a channel into the river of a depth of 15 feet at low water, sufficiently wide for all practical purposes. The average rise and fall of the tide at the mouth of this river is 16 feet, as laid down by the surveys, making a depth of 31 feet, without any further improvement, at high water. I should say the spring tides, which occur at the full and new of the moon, rise sometimes as much as 21 feet, but the average rise and fall of the tide is 16 feet. This river, from its mouth up to and beyond the point where the canal enters into it, has a depth of 15 and 18 feet, and in parts as high as 25 feet at low water, giving also at high water from 31 to 41 feet without any further improvement.

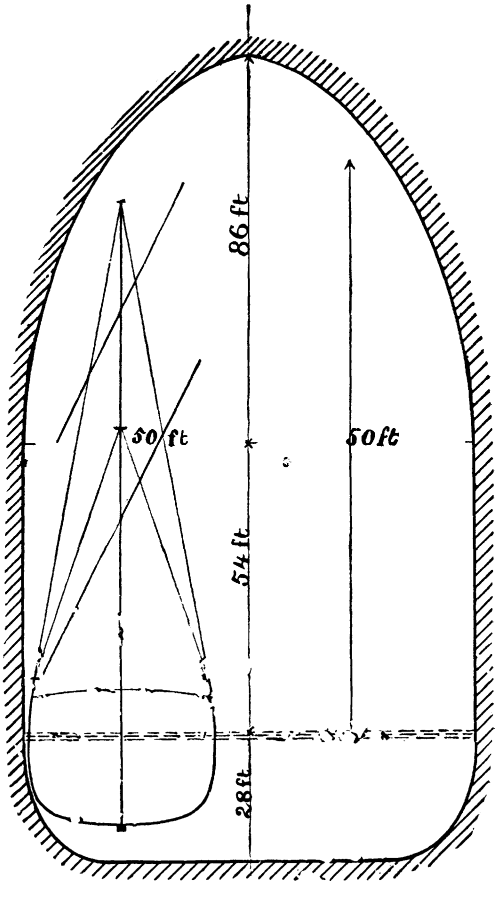
Judge DALY : Does that extend as far as the tide extends ?

MR. SHELBOURNE : No, sir ; not as far as the tide reaches. You will see that the river makes a large but sudden and very closely returning bend here where the canal would enter it. The distance from this bend and the canal cutting to the mouth of the river is six miles, and it is for that distance that I speak when I say that the survey shows there is from 15 to 25 feet of water in the river at low water. The tide extends up this river, as the river runs, for a distance of 27 miles ; but as you come up around this great bend where the canal enters the river from the northward, the river has its direction quite from the eastward and away from the line of the canal, so that you see, as the canal enters the river comparatively near its mouth and a long distance below the head of tidal action, any freshets in the upper reaches of this river cannot materially affect its level where the canal enters it. As you pass up the river from this great bend, its bed rises more rapidly until you arrive at the head of the tide—that is to say, that the river at the head of the tide would have an elevation of 16 feet above the river at its mouth in the bay of Panama, and the tide would influence the river up to that elevation, or, more correctly speaking, to a point where the ordinary surface of the river is elevated 16 feet above the surface of low water in the bay of Panama, a distance of about 27 miles. The head of the tide water in this little river, the Mamoni, closely adjacent to the line of the canal, is in a direct line from the great bend where the canal enters the Bayano, a distance of four and one-sixth miles ; so that it is apparent that the depth of open cutting in the canal for this distance will vary only up to

16 feet above low water in the Bay of Panama, and from the head of tide in the Mamoni to the base of the mountain, where the tunnel would commence on the Pacific side, the elevation above low water would vary from 16 feet to 75 feet close up to the base of the ridge. The exact length of cutting from an elevation of 75 feet to that of 190 feet I have not been able to determine from the data I have had before me, but I should say less than one mile.

It will be observed that that part of the Bayano river to be utilized in connection with the canal has a width of nearly half a mile for one-third of the distance from its mouth.

Now, in regard to the tunnel and its proposed width and height. I have had a drawing made which will represent to you the section of the tunnel :



There have been various widths proposed for it, from 60 to 80 feet. Considering that it might be desirable that the largest vessels now afloat should pass each other within the tunnel—one going in one direction and the other in the opposite direction—and considering the progressive size of the vessels of the future, I have made this tunnel 100 feet wide at the surface of the water. It is also 100 feet wide at a depth of about 14 feet below the surface of the water, and to a height of 54 feet above it. Angles are avoided in the bottom of this tunnel, and the sides are seen to curve inward towards the floor, leaving a convenient fillet of rock in the corners. The height of the tunnel altogether, from the bottom to the top, is proposed to be 168 feet, with a depth of water of 28 feet. The springing of the arch is to begin at 54 feet above the surface of the water, and continue thence a further perpendicular height of 86 feet to the crown—making the latter point 140 feet above the surface of the water.

The drawing shows, in its left-hand section, a representation of the ship *James Nesmith*, a sailing vessel of 2,000 tons. The position of her topmast-head is shown when the side of the vessel is against the side of the tunnel. I have shown it in that way in order to answer the objection of those who argue that a vessel coming in contact with one side of the tunnel would injure its masts, yards and rigging against the decline of the tunnel arch. The yards of the vessel are shown cock-billed—that is, having one end of them brought downward on an inclination as shown in the figure. Both ends, therefore, of the yards are brought within the perpendiculars of the sides of the vessel. It will be seen by this drawing that, when the side of that vessel is against the side of the tunnel, the topmast-head will not touch the arch—it comes, at least, 10 feet from the decline of the arch. The width of this ship is 41½ feet. The figure shows the space between the central line of the tunnel and the body of the ship when she is placed next to the side of the tunnel; consequently, two such ships might pass each other in this tunnel, leaving a space of 17 feet between them.

The arrow-head in the right-hand section of the drawing shows the relative position of the topmast-heads of the steamers *City of Chester* and *City of Berlin*, of the Inman line, when passing each other in this tunnel. This arrow-head shows where the topmast-head of each vessel would come—the one on one side of the tunnel and the other on the opposite side—with reference both to the central line of the tunnel and the declines of its arch. I am told that the height of the topmasts of these steamers equals those of any now afloat. You see that the clear distance, sidewise, to the arch is about 8 feet; while, if one of these vessels were passing along in the central line of the tunnel, the vertical clearance would be more than 22 feet. I should say, at this point, that it is proposed to have longitudinal fenders fastened against the sides of the tunnel, of heavy timber, so that a vessel passing through it will never come in contact with the rock nor any of its roughness.

Again, sailing vessels in passing through the tunnel will always be in charge of a tug, alongside, and the tug being the lowest by far, with its smoke-stack and rigging, will take its position next to the side of the tunnel, keeping the vessel as near as possible in the central line of the passage. A steamer in transit can keep its direction and position with the greatest facility, for the water in this tunnel will be always quiescent.

In the work of excavating this tunnel it is proposed to begin at the top and excavate first a top section or heading of the main tunnel. This heading, or preliminary tunnel, as I shall call it, will have a vertical section of about 40 square yards, and, conforming in its arch with the arch of the main tunnel, will have its floor 15 feet below its crown and be about 30 feet in width; so that, at the sides of this preliminary tunnel, its roof would be 7 to 9 feet above its floor. If a section of 40 square yards be assumed for this excavation, a length of seven miles would give 492,800 cubic yards. Of course this preliminary tunnel is commenced upon each end—giving, so far, two working faces. If shafts are deemed desirable to expedite the work, it is designed to provide for three shafts, located at the most feasible points on the top of the mountain, and sunk to the level of the floor of the preliminary tunnel, and that would give us eight working faces altogether, if such rapidity of operation should be found necessary. It may be observed, here, that the St. Gothard tunnel is being excavated without shafts, a length of nine and one-quarter miles, and the whole time is a little more than seven years.

The cost of this preliminary tunnel has been placed at $10 a cubic yard, and would amount to $4,928,000. When the work I have just named is completed, all the tunneling work, which it is proper to name as such, is done. The rest is to be classed as work of another character.

Now, in regard to the price of tunneling work. A committee of the Paris Congress put upon the excavation of this tunnel upon the San Blas route, and, in fact, upon all the routes where tunneling was required, the greatest price that had been paid for the excavation of tunnels when they were excavated by hand-drilling and the explosive was gunpowder ; and, more than this, they estimated the whole immense excavation, all of it, at the price for driving a small tunnel or heading, so that at $10 per cubic yard for tunnel, the San Blas canal, with 20,727,715 cubic yards of what the committee would call tunnel rock, would really amount to the total sum they named—somewhere about two hundred and sixty millions of dollars. This will show us how hasty and superficial were the calculations of the majority of those members of the committee having this subject in hand. Louis Favre, the contractor for the St. Gothard tunnel, did not place such figures upon the San Blas tunnel, for he made the cost at less than one hundred millions of dollars while estimating for a length of about nine miles.

Now, let us see how the question stands. The contract price for the Hoosac tunnel in 1869, for the entire excavation of the eastern section, was $11 per cubic yard ; that contract was made in December, 1869, before the active era of nitro-glycerine, or dynamite, which is a modified form of the same substance, and before the use of machine drills in that tunnel, as it stood from the hands of previous operators. It was only after Mr. Shanly had got fairly at work under his contract that he introduced the Burleigh drill ; and they kept perfecting their machinery from month to month and from year to year. Mr. Mowbray in 1869 was eagerly at work trying to perfect nitro-glycerine, so as to give the best results and make the explosive the least dangerous. Here, then, and in this condition of the art in 1869, with its inflated prices and gold premiums, there was a contractor who undertook to make a contractor's profit out of a small railroad tunnel at $11 per cubic yard.

The contract for the St. Gothard tunnel was made August 7th, 1872, and the contract price for the excavation of the tunnel amounts per cubic yard in our currency to $6.72. Here was another contractor who, thus early in the art, could find a contractor's profit in such a small tunnel at such low figures ; but his mind was open to the future of his work, in the midst of the success of which he laid down his life. The vertical section of the St. Gothard tunnel is about 72 square yards.

Again, as to rapidity of execution in tunneling work: In 1863 the progress made in the Mount Cenis tunnel with hand-drilling and powder as an explosive was an average of a foot and a half per day. After they had commenced to introduce power drilling and the Sommeiller machine, the progress they made was three times greater—that was four and a half feet per day. When Louis Favre took the contract for the St. Gothard tunnel in 1872, the Hoosac tunnel was then in the rush of its progress under Mr. Shanly. Shanly completed his contract and made a provisional settlement December 22, 1874, and the tunnel was put to use the following year. Mr. Shanly said in 1874 of the machine drills used: "The use of the machine drills saved about two-thirds of the expense of drilling. The expense of labor would have been, I think, fully three times the cost of machine drilling. To have done this work by hand-drilling would have taken, I should estimate, not less than twelve years." This was the work, even at that time, accomplished in less than five years.

In the St. Gothard tunnel, from 1875 to 1877, with the greater perfection of explosives—for they had come to use nitro-glycerine by mixing it with an earthy material, making a compound consisting of seventy-five per cent. of nitro-glycerine and twenty-five per cent. of the adulterant and calling it dynamite, from a Greek word signifying power, and which is the standard explosive they now use—in 1875 to 1877, I say, with better explosives and improved drills, they made a progress of five to one; that is to say, they excavated their tunnel about five times as fast as was the progress in the Mount Cenis tunnel in 1863 by hand-drilling. Now, in the years 1878 and 1879, by the general improvement of the whole administration in the St. Gothard tunnel, they are making a progress of more than eight to one, or about 13 feet per day, through granitic gneiss, in a single heading. So that now, if they can excavate and remove rock from a tunnel eight times faster than they could fifteen years ago, you may readily see how much easier—how much more feasible—a tunnel has become to-day, on an Isthmus canal route, than at the time, in 1870, when the surveys of Selfridge were made. Indeed these naval officers, in their sphere of action, were ignorant of and had not conceived as possible these strides of inventive and engineering skill. How much value then—and I appeal to the judgment of each one of you—how much value must we now place upon the reports and opinions of these naval officers as to the comparative merits of a route, with a tunnel or without one, at the time their surveys were made?

The object of these surveys by the government was to find a low pass through the Cordilleras upon which they could construct a canal; and one of the conditions of the problem was that they should find a sufficient water supply to furnish the locks of the canal. They had hardly conceived the idea of making a tunnel; and if they were to have a tunnel as Selfridge proposed for the Napipi route, it was to be a short one, and only an absolutely necessary adjunct to permit them to realize the other conditions of water supply and a lock route through as low an elevation as it was possible to find.

I have a letter from Mr. W. Shanly, dated in September, in which he says that he would be willing to take the contract to drive the preliminary tunnel I have explained to you, for the San Blas route, for $9 a cubic yard. I have placed the cost at $10. Of course Mr. Shanly's price provides for a contractor's profit above the real cost of the work.

Now, in regard to the remainder of the work. You will see that when this preliminary tunnel has been excavated as represented by the section I have named, that only a very small percentage of the excavation has been accomplished. Engineers agree—Mr. Shanly has so stated, and Mr. Latrobe, and, I believe, Mr. McAlpine—and indeed it is clear to the mind of an engineer that when the preliminary tunnel is once driven the remainder of the work becomes nothing more than open cut work, with the extra advantage that you have the protection of a roof over you, so that the work with electric light can be carried on twenty-four hours a day the year round, without exposure to the vicissitudes of the weather, or the malarial atmosphere of swamps and vegetable decay.

Now, if the estimates for open cut rock upon the Nicaragua route, as its advocates have placed them, should be applied to this tunnel open cut work here, the result would be that the whole cost of the tunnel would be only $30,837,644, that is allowing $10 per cubic yard for the preliminary tunnel, and calculating the remainder at $1.25 per cubic yard. But I have endeavored to show on several occasions that the estimates of the advocates of the Nicaragua route for their open cut rock work are entirely inadequate. I have more than doubled their price for this class of work, and placed the excavation of the remaining portion of this ship canal through the mountain at $3 per cubic yard; so that the cost of this great tunnel—I mean the excavation of it—would be something like $65,000,000. I have the exact figures somewhere, but not just now at my command. If, however, sixty feet should be thought wide enough for the passage through the mountain, the cost would be reduced to about $40,000,000.

Every one who has objected to a canal route by way of San Blas has brought his first and chief objection and his last and reiterated objection to bear upon this tunnel : I suppose because all the other features of this route, except what lay in their ignorance, were admirable and pleasing to their minds, and the tunnel was the one thing to decry. They say that it is impossible to calculate its cost, and they assume to fear that the mountain would tumble in on the workmen, as if it were a quicksand, or that everything will be drowned out of it, as though it were a cloud of waterspouts. I have been careful in placing the figures upon this work, and I think they will cover the maximum. If the open cut work upon so large a scale as this could be done for $1.50 or $1.25 per cubic yard, you see that the whole cost would be reduced more than one-half the highest figures I have given; but I prefer to be safe in this respect.

After the preliminary tunnel has been driven into the mountain on either side for a certain distance, a multitude of workmen is placed upon this open cut excavation, and the tunnel is enlarged from the top downward in benches of rock and in convenient sections, always providing a depression for the drainage of infiltration. A track is laid in the tunnel and the debris is railroaded out on flats and dumped at either side of the proposed canal upon the low ground adjacent to the sea, and perhaps extending a certain distance into the harbor of Mandinga, and widening out on either side so as to form a convenient mouth for the canal.

But the great question has been whether the rock in the line of this tunnel would be homogeneous enough so that a natural arch would be self-sustaining—whether, in fact, the rock there was not entirely disintegrated and full of broken pieces, seams, cavities and cracks, so that, as we attempt to go through it, as one person expressed it to me, it would be like going through a mountain of cobble-stones. Indeed, some of the objectors seem to have agitated their minds into a lather of swollen apprehension on this subject.

It is sufficient to say that, through the base of the Cordillera upon this route, the rock is largely, if not entirely, granite rock.

Judge DALY: Is that the report of Mr. Kelley's engineers, or is it the surface indications ?

Mr. SHELBOURNE: That is not the report of Mr. Kelley's engineers, because there were no geologists with Mr. Kelley's engineers; they made an engineer's survey. But this section of the isthmus has been examined, embracing both the San Blas route and the coast and interior further south at Caledonia bay, by J. Petigru Carson, mineralogist, and E. W. Bowditch, assistant mineralogist, of the expedition of 1870. Besides, the geology of the whole lower isthmus, embracing the Gulf of Uraba and the Atrato region, on the Atlantic side, and also the Pacific side, including the Tuyra region to the dividing ridge, and the coast from Limon Bay to Panama, and across on the line of the railroad to Aspinwall, has been examined and carefully reported upon by Dr. A. G. Mack, of Cambridge, Mass., and the specimens he brought home are now, by permission of the Secretary of the Navy, lodged in the geological collection of the Cambridge University. We have also various information from the works of older geologists and others who have exploited these portions of the isthmus, among them being Mr. Arthur Schott, accompanying Michler's survey of the Atrato-Truando region. On the San Blas route the boulders and other loose specimens found in the beds of the rivers up their courses were examined, and also the outcrop upon their banks and upon the various ridges of the mountain; besides, immense gorges of syenite were found, one of them extending for half a mile.

There is one very important thing, then, which can be said of this section of the isthmus that cannot be said of any other portion of it through which the various proposed routes for a canal pass. It cannot be said of Panama, nor of Nicaragua. It is this: that the San Blas Cordilleras are composed, on the Atlantic side at least, and through the bases of the main ridge, of the older crystalline unstratified rocks, granite and syenite, which is a species of granite. The common granite is composed of quartz, feldspar and mica. Syenite is that species of granite in which the mica is supplanted by hornblende. Now, these older crystalline unstratified rocks are the very oldest of all the rocks that appear upon the face of the earth. They are called primary in the books. Indeed, before any animal or vegetable life came upon the earth these rocks formed the ribs, we might say, of the continents. They are coeval with the foundations of the earth, so that we may write upon them an inscription quoted from the third canto of Dante's Inferno:

> "Before me created things were none, save things eternal."

This part of the isthmus, cutting it off near to Panama on the west and north on the one side, and taking the Bay of San Miguel and the Tuyra river over the divide to the Atrato valley and the Gulf of Uraba, as the limit towards the south and east—this part of the isthmus was originally a mountainous island. The whole of the lower valley of the Atrato river is an alluvial deposit. The part of the isthmus between the Bay of San Miguel, the Tuyra river and the Atrato valley on the north, and Cupica bay on the south, was upheaved long after the bases of the San Blas Cordillera appeared. This southern region shows the later tertiary formations. The same may be said in regard to the broken region between Panama and the Bay of Colon, which shows scarcely more than a series of detached hills, irregularly placed with reference to each other, like a lot of tumbled biscuits on a tray. The waters of the Atlantic and the Pacific were, at one time, united both in the region between Panama and Colon, and between the Bay of San Miguel and the Atrato valley, which was, in early ages, a part of the Gulf of Uraba, the junction of the two oceans being in the general line of the Tuyra river. So that we have to the north of this river the foundations of the Cordilleras range and its spurs composed of the primary unstratified rocks, and to the south of it, towards Cupica bay, the volcanic rocks, belonging to a much later era, and between the two formations, rocks of what is called the transition series. Here is a general map of that part of the isthmus, which I have taken from the series accompanying Commander Selfridge's report, and is map No. 1 of that series. You will see on it the general relation of the two divisions of the Cordilleras south and north of the Tuyra river. You will see, as you pass from the Bay of San Miguel up Darien harbor and the Tuyra river, the peculiar broad pockets and connecting reaches of water made by the banks, so unlike an ordinary river, and as you get up towards the ridge, or rather the depression or division between the two formations at the headwaters of the Tuyra, you will see how the mountainous section of the isthmus, on the north and east, is divided from that towards the southwest, so that, in a general way, they may be said to lap by each other. You see that the region at the headwaters of the Tuyra is filled also with numerous detached hills like the region at Panama, and the Rio Chucunaque, coming down from the far north and the middle of the older part of the isthmus, makes a very angular turn below Yavisa, and flows with the Tuyra towards the northwest and Darien harbor. Before the upheaval to the south, this river doubtless flowed into the passage between the two oceans, where now it makes its sudden bend to the northwest, and Darien harbor and the Bay of San Miguel are nothing more than the depression that was left after this later upheaval. In the fact of this passage here between the two oceans we may largely find the origin of the extensive alluvial deposits of the Atrato valley. The tide rising twice a day from 17 to 24 feet in the Pacific at this part of the isthmus, and scarcely 20 inches in the Gulf of Uraba on the Atlantic, the swift tidal current through the passage, always in one direction, must have carried immense quantities of alluvium with it. To the same cause I attribute the large swamp area adjacent to Colon in the Panama region.

Here, then, are two facts which mutually support each other. First, the fact that granite and syenite, both in mass and as boulders, are found *only* in the region of San Blas, and south towards the region of the Upper Tuyra, and nowhere else on the whole isthmus, from above Nicaragua southward, proves the fact that the transition rocks exist somewhere between the old and the new—and sure enough, the fact that the formations found in the Upper Tuyra region are of this series, and reveal their fossilliferous character by their marine shells, proves both the fact that the waters of the two oceans once joined in this region, and the fact of the older formations on the one side and the later on the other. So that, when the upheaval took place in the later tertiary period which closed this passage, these broken hills which were thrown up here partook of the character of each adjacent formation.

Again, as to the evidences of the character of the San Blas Cordillera, on the Panama side. We see that the continuous ranges of these Cordillera, running towards the west, terminate abruptly here, and are succeeded by a series of lower detatched hills, as I have said. None of these hills are of a granitic character, but are the result of volcanic eruption. The fact, however, appears that in the playas of the Chagres river at Mamey and at Matachin, we find the older crystalline pebbles, the granite and the syenite. Now, the Chagres has its sources in the high elevated San Blas Cordillera, from which these pebbles have been driven by the river current ; but no pebbles whatever of a granitic character are found in the beds of the rivers coming from the opposite direction. The later eruptive origin, then, of the rocks on the Panama route, proves the fact that the Chagres river at one time found the waters of the sea at Matachin. This is also evidenced by the fact that, close to the highest ridge of this part of the isthmus, fossil corals have been found, and up the Chagres limestone deposits filled with fossil shells, while in numberless places along the railroad the strata of the volcanic tuffs are apparent, and quarries of it for the use of the railroad have been opened containing particles of gold belched out, and fallen into the sea or strait with the volcanic cinder.

Following the isthmus northward to Nicaragua, we will find the rock to be of the same general character as at Panama. The geologist connected with the survey of the Nicaragua route says the rock they found there was mostly of the later tertiary period, volcanic, basaltic. They found some crystalline limestone, which belonged to the group of sedimentary deposit, and was slowly upheaved from the sea. I think, therefore, upon the evidence presented, the distincive fact appears that of all this region of the isthmus, commencing at Uraba, and away to Nicaragua, the only part of it where the primary formation appears—the oldest of all—the unstratified rocks, the granite and the syenite, is in the range of the San Blas Cordillera. This fact, then, of the character of the rock to be found on the line of the San Blas route, will give us an indication of the work before us in piercing a tunnel, and the homogeneity and stability of the material. Further than that, we cannot say. Nobody has bored into the heart of that mountain to determine just what may be its character and to what extent we may depend upon the uniformity and closeness of its structure. It may be, and the probabilities are, that the most of the rock found in that tunnel will be sufficiently homogeneous to be self-sustaining.

The general reputation of granitic rock for continuity and closeness is pretty well sustained by the fact that it usually excludes water infiltration. Of 2,000 metres of granitic gneiss, of a single stratification, in the St. Gothard tunnel, the work was quite dry.

But if, on the other hand, we admit the probability of finding demoralized rock, we know the proportion of it in the tunnels that have been excavated. Let us take at random the Hoosac tunnel, as the nearest and most prominent example. Mr. Shanly told me recently that they found various characters of rock there, some granitic rock, but largely mica schists and other schistose formations, and of 25,000 feet in length, which he excavated under his contract, only 4,000 feet needed any arching of masonry. Here you find a tunnel made with a very flat arch—a tunnel in a very variable climate, the temperature now up to 100, now down to zero and below, freezing the water in the crevices. Upon the isthmus we have a nearly uniform temperature of 70 to 85 and perhaps 90 degrees. There would be no snow—no freezing. The arch would be a gothic arch, as shown here in the figure. If we should find as great a proportion of the length of the tunnel that would need arching as they found in the Hoosac tunnel, which would be in this case a trifle more than one mile, it is proposed that an arch be constructed resting upon abutments in the natural rock sides of the tunnel, 50 feet on the curve of the arch below its crown, which would make each segment or rib of the arch a length of 50 feet. Now, to construct that arch with these ribs made of cast iron, would give about seventy-five per cent. more strength, with only about one-third of the dead weight of an arch made of the best of stone, as granite, five feet in thickness over that whole space. A section of one of those ribs may be roughly represented by a plain letter T, with the head stroke shortened and the body stroke lengthened. The width of the head, which would be on the greater or outward curve, next to the rock, would be one foot, and the depth of the remainder of the section of the rib would be two and one-half feet at the crown of the arch, and three and one-half feet where it rests upon the abutment. A shoe or bearing plate would be cast on either end, the full width of the head and depth of the section, the shoe, on the lower end, resting on the abutment, and the bearing-plate on the upper end coming in contact with that of its fellow at the crown. As these ribs would be placed close together, each successive pair in contact with the preceding, it will be seen that each foot in length of the portion of the tunnel arched in this way would be represented by a pair of these ribs. The metal in the ribs would be of a uniform thickness of two inches, with a fillet at the junction of the head with the body. But objectors will say that the iron will easily perish with rust, and so crumble away. Now, we know that iron rusts in proportion to its purity. Cast iron rusts very much more slowly than wrought iron, and wrought iron chemically pure rusts most freely of all. But these ribs or segments are so devised that neither a drill or a chisel will touch them ; and by lining or sifting the mould with the elements of glass, or the powder of ground glass of the commonest description, you will cast upon those ribs a coat of glaze, so that they would be protected for an indefinite period of time from rust. These segments of the arching being placed close to each other, side by side, the backs of the whole, when in position, would represent a continuous arch-roof of iron, and the space between this roof and the irregular rock above, perhaps from three inches to a foot, would be filled with concrete. The arch thus constructed could be rapidly and easily put in position, and the cost would be less than one-half that of a granite arch of the thickness I have named. It would be very difficult to put up large granite blocks in an arch of that character, and it would involve a great deal of work, and be very slow of accomplishment. Such an arch of iron has therefore been proposed, if it should be found that an artificial arch would be necessary; and if so, our present examples teach us that it would only be required, in this tunnel, for about the length of a mile.

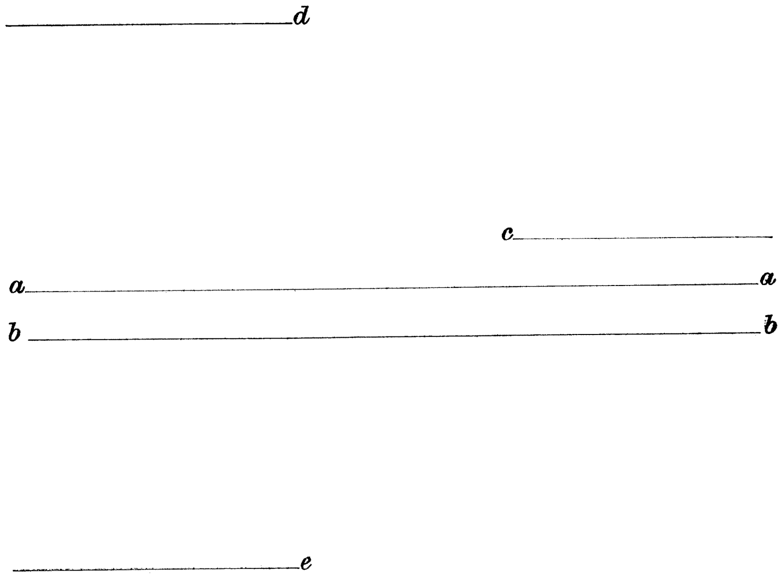
I believe I have spoken of all the points in the excavation of this tunnel, except this matter of infiltration. It will be seen that in the excavation of the preliminary tunnel, whose floor would be 175 feet of elevation above the sea, the drainage of the infiltration could be made perfect at each end ; and only in case shafts are sunk from the top of the mountain to expedite the work, would pumping be needed, and then only in the shafts. While there are peaks of the Cordilleras which rise very high above the general plateau of the elevation, there may be points selected in this plateau where these shafts can be sunk at perhaps an average of 500 to 600 feet above the level of the sea ; so that the shafts would be of that depth minus 175, the depth from the floor of the preliminary tunnel to the sea level, or altogether a depth of the shafts of from 325 to 425 feet. In the

Hoosac tunnel they pumped up the water of infiltration for the whole working central section through a shaft of 1,030 feet deep. They had shafts in the Sutro tunnel of 800 or 900 feet in depth—twice and three times the depth proposed here at San Blas. But, leaving out of view the question of the shafts, this preliminary tunnel can be perfectly drained from each end, while the work is in progress, without a gallon of pumping, and the drainage could be equally perfect while driving through the whole depth of the tunnel open cut work, until you get down to the level of the sea ; and then first, of all the work, would the water of infiltration need to be removed by pumping; but that would only be for the depth of the excavation below the level of the sea, varying from nothing to a depth of 28 feet.

Now, where you have a depth of 1,100 or 1,200 to 2,000 or 3,000 feet, from which to pump water, it is a different problem altogether from that where you have only to pump it up an ordinary depth of 28 feet. The large centrifugal pumps, now in common use, would throw almost a Niagara of water up from so small a depth into sluices which would carry it off. By excavating this portion of the tunnel in consecutive sections of half a mile, Mr. Shanley has stated, and I perfectly agree with him, that there would be no difficulty whatever, with ordinary pumps, in easily keeping the water free from this excavation while it is being made to the depth of 28 feet below the level of the sea.

Of course the excavation of the five miles of the canal between the tunnel and the harbor of Mandinga would be done in the lower portion next to the harbor by dredging machines, thus bringing the navigation up to within about two miles of the mouth of the tunnel, and this two miles being excavated down nearly to the sea level, a bulkhead of rock would be left towards the sea end of it, perhaps 20 feet thick, while the rest of it is being excavated below the sea. The same condition, as to open-cut work, drainage and pumping and method of procedure, would obtain upon the Pacific side as upon the Atlantic; a considerable portion of it would be done by dredging machines, commencing at the debouchement of the canal into the river Bayano.

Now, in regard to the tide levels of the two oceans, and in regard to the tide-lock that would be required for this canal. As I have said, the mean rise and fall of the tide in the harbor of Mandinga, upon the Atlantic side, is eight-tenths of a foot. Now, that being the mean, the extreme would be somewhere about two feet at spring tides, and with the wind blowing from a direction to pile up the water in the harbor, or the reverse. So that, in order to keep a depth of water in the canal of 28 feet at all times, without a gate or any artificial structure upon the Atlantic side, it would be necessary to make the level of the water in the canal to correspond with the lowest low water level in the Gulf of San Blas. The conditions of the whole case will be readily represented by some parallel lines shown on this diagram:



The line *a a* will represent the level of half-tide, which is the same in the two oceans. Of course, it is readily understood that if there were no tide in the Atlantic, and no tide in the Pacific, and the waters of the two oceans rested quietly without tidal movement the same as in a small lake or pond, they would be at the same general level in both oceans, due to the law of terrestrial gravity ; and that level would be the level of half-tide as things at present exist, and would be represented by the line *a a.* Although it is not the practice in popular usage, for the purposes of this illustration we will say, when the tide rises it is above *a a*, and when it falls it is below *a a*. Taking the distance between the lines *a* and *b* and between the lines *a* and *c* to be in each case one foot, *c* would represent the maximum rise of the tide and *b* the maximum fall of the tide at the Atlantic end of the canal; the mean rise of four-tenths of a foot above *a*, and the mean fall of four-tenths of a foot below *a*, coming of course between the lines *b* and *c*, it is not necessary for our purpose to represent. Now, instead of taking the half-tide level *a a* as the proposed level of the water in the canal, we take the line *b b* for that level ; because, if *a a* were taken as the level of the water in the canal, when the tide had fallen in the Gulf of San Blas to the line *b*, the water in the canal would run towards the gulf, for the water in the gulf would then be one foot lower then the assumed level of the canal. To avoid such a state of things, therefore, it is proposed to make the level of the water in the canal correspond with the level of lowest water in the Gulf of San Blas, that is, the line *b b*. On the Pacific side the mean rise and fall of the tide is 16 feet, that is, eight feet rise above the line *a*, which is represented by the line *d*, and eight feet of fall below the line *a*, which is represented by the line *e*. But the line *b* has been assumed as the level of the water in the canal, and therefore, in the ordinary movements of the tides on the Pacific, the tide-lock at that end of the canal would, a part of the time, lock upwards from *b* to *d*, a height of nine feet, and the remainder of the time lock downwards from *b* to *e*, a descent of seven feet, these conditions of lockage alternating as the tide should be high or low in the Pacific. At times, however, the tide rises and falls in the Pacific at this part of the coast more than 16 feet, in which case the lockage either way would be correspondingly increased.

The tide lock upon the Pacific end of this canal would be constructed of a length of 1,125 feet and a breadth of 100 feet ; the gates, instead of being double at either end of this lock, would be single, and would be sliding instead of folding gates, and move on rollers, the advanced end of the gate moving into a recess across the opening of the lock, so that the pressure from either side will not disturb it from its position as the tide may be high or low. These gates need not be tightly fitting, for, since the two oceans are the water supply, the escape of more or less water in the one direction or the other is of no consequence.

At the middle division of this lock there would be a slight contraction in its width, and here would be another gate of the same construction, which would ordinarily be left open. Now, you may conceive that occasion may arise for the removal of one of these gates for ordinary repairs ; or one of them may become damaged by accident, in which case you always have a tide-lock between the other two, of a length of 560 feet, and either one of the three may at any time be regarded as an extra gate, and be removed for repairs. It will be observed, that a tide-lock as here proposed to be constructed and used, is not at all comparable with the detail lockage and conservation of water supply, as contemplated on the Nicaragua route. There the gates must be close fitting, to save their lockage supply, and double and mitreing to each other, that they may be close fitting, and the locks made as small as practicable, and locking only one vessel at a time, all for the purpose of saving the water. In our tide-lock, however, prodigality is not waste, for what escapes from the Pacific goes to the Atlantic, and *vice versa ;* and, until both these oceans run dry, we shall always have enough. So that, in our tide-lock of the length and width proposed, six ships of 1,000 tons each can be passed through in one lockage.

To fill and deplete this tide-lock, it is proposed that the main gates shall have subsidiary gates arranged within them, to be raised or lowered, so as to open and close a passage through the main gates 60 feet wide by six feet high, located below the level of low water in the gate next to the Pacific, and at any convenient distance below the water in the canal at the opposite end of the lock. The time required to fill the entire undivided lock to a level of nine feet would be less than three minutes.

It hardly seems to me that the question of calms in the Bay of Panama needs any more explanation than I have already given it, both here and elsewhere. But I want to say that this subject has been investigated and reported upon, under the concurrent written instructions of Commander Selfridge and Admiral Ammen, then in the Navy Department, by Lieutenant Frederick Collins, who was attached to Selfridge's expedition, and who was ordered to inquire and report upon the winds and tides of the Pacific ocean, with particular reference to the functions of a canal constructed on the Atrato-Napipi route. This is the gallant Collins who, as we all know, never stood up against the flag of his country, nor forswore the oath which made him one of the trusted protectors of our constitutional Union and our civil liberties. In his investigations he had occasion to make some observations and pass some criticisms upon that other former officer of our Navy, Lieutenant Maury, and to point out a great discrepancy of view between the well-known authority, Kerhallet, and his own countryman with reference to the general subject of his inquiry. Now, Lieut. Maury had the whole Pacific ocean for the subject of his inquiry, away across to the China seas, and so did Lieut. Collins, and yet, while he was to make all the results of his work to converge on the edge of the Bay of Panama, at the Pacific end of the Atrato-Napipi route, he does not even once, with reference to calms, mention the Bay of Panama in his report. Was this gallant officer overawed in his judgment by the dominant officialism of a then different interest, or did he really forget to point out to his superior and directing officers the one important fact they should have known as against that route, if the objection of the calms which the Nicaragua advocates now spread with so much *wind* of talk over the whole Bay of Panama were really a valid one ? But leaving them to their efforts, I have to say there are, generally speaking, up and down this Pacific coast of North and South America what are called coast trades, or, localized, the monsoons of Mexico. When the sun is going south these winds blow towards the south. They go with the sun. When the sun is coming north, they blow towards the north. It is 300 miles away to the westward from the general line of this coast that the great system of winds of the Pacific are located and extend across to the China seas. It is true there is located in the general system of the winds of the Pacific a belt across the Pacific near the equator, called the belt of the "doldrums," but this word does not mean calms by any interpetation, but rather light and variable winds, with storms of wind and rain and squalls and calms thrown in; or, as the sailors call it, "dusty weather." But what has this to do with the coast breezes, which by common report we are told exist in the tropics? And yet, if the logic of the objectors should hit the real fact, instead of an assumed one, it would prove too much ; for a vessel going through a canal by the Nicaragua route, and destined to any of the ports of the South Pacific, Australia, New Zealand, the west coast of South America, and the numerous islands south of the equator, would have to pass, in the voyage, through that whole belt of "calms" which they use so diligently to give size to their statements when objections to any more southern route than their own are in place to be heard.

But they are careful to locate these "calms" precisely in the Bay of Panama. They say a vessel would be likely to be held in this region for perhaps three months, not able to get in, or once in, not able to get out. Surely, in their view, it must have been here where Coleridge's Ancient Mariner conceived the situation of a "painted ship on a painted ocean."

Now, I have the practical observations and experience of sea captains in the California trade, who have gone into the bay of Panama time and again. I have the statement of the President of the Maritime Association of the Port of New York, who sent the first vessel to California, with supplies in the early days of its *El Dorado*—whose firm in the height of this California trade sent as many as 125 to 130 vessels with various materials in a single year to Aspinwall and Panama, the one and the other, and that they regarded Panama as favorably for access and sailing convenience as any port on the coast. That, then, is the practical statement of the case.

Judge DALY : Are there any earthquake difficulties on the San Blas route, so far as known ?

Major SHELBOURNE : There are none, so far as we know, from the earliest records. We have, on the contrary, the geological character of this portion of the isthmus, and the notable fact that in all this region of the older rocks we have not a sign of a crater, living or dead. Of course I do not wish to be understood to mix up earthquakes and volcanoes as necessarily coexistent in the same localities; but, while earthquakes are due to the mighty pent-up forces under the crust of the earth out of their equilibrium, and seeking relief, the volcanoes are the local, the open and the speaking mouths of the earthquake energies.

Judge DALY: About how far does the volcanic rock come down upon the isthmus ?

Major SHELBOURNE: It comes down on the north to the Panama region; and, as I said, this portion of the isthmus, from Panama up to, and I know not how far beyond, Nicaragua, is entirely of a later formation—a secondary sedimentary, and a tertiary volcanic origin. There is also basaltic or volcanic rock in the San Blas region, but it forms the caps and the overcoat of the Cordillera, so to speak, while the bases of the mountain are granitic. As to the activity of earthquakes in the region towards Nicaragua, I was informed after the last meeting in this room, a week ago, by one of the gentlemen present—I think the one who spoke last, and was called upon by Mr. Menocal to give some idea of prices of excavation in Nicaragua, because he had been connected with engineering work in Costa Rica—that during the past year advices had been received that in one of the towns of Costa Rica, which, as you know, adjoins Nicaragua, a cathedral had been rent and very much damaged by an earthquake. Now, in the San Blas region of the isthmus, the region of the very earliest rock formation, as I have said, so many ages have elapsed since it was the scene of active volcanic energy, that nowhere are there any traces even of extinct craters to be found. But if you go either north or south, on the one hand only as far as Mexico, and on the other to the Colombian territory itself, at the very northwest part of the South American continent, we find regions of active volcanic action, an example of which may be found in the Colombian State of Tolima, where there is an active volcano identical in name with the State. In fact, geologists tell us that under the South American region of the Andes, from Colombia on the north to Chili or beyond on the south, there are whole lakes of melted lava, involving regions of hundreds of square miles in extent. It is a well established fact that earthquakes have their origin and are most frequent and violent in active volcanic regions. Now, the fact that from Panama south to the Gulf of Uraba no indications of even extinct craters exist, and nothing more than the very slightest sensations of earthquakes have been felt, and no damage done discoverable from the time of the earliest records, points sufficiently to the conclusion that active volcanic and subterranean action have entirely ceased in this part of the isthmus since remote ages. In like manner we find in other parts of the earth the same conditions to exist, for ancient volcanic mountains are met with in Hungary and in central France, of whose eruptions no record exists, and many parts of the Rocky mountains give evidence of the same character. Fisher's Peak in Arkansas is also said to be an extinct volcano. In 1863, the best authorities enumerated eighteen active volcanoes in Central America. As none of these are to be found in the Columbian part of the isthmus, they must be credited to the more northern countries, of which Nicaragua and Honduras are the central states. Within the past month a map has been published, the data of which is the work of Dr. Kuyper of Holland, giving the location of thirty-eight volcanoes between the southern bounds of Costa Rica and the proposed Tehuantepec route on the north, of which number ten are found in Nicaragua. It is not stated how many of these are active, and only the figures of 1863, which I have given, will enable you to form an opinion.

It seems, moreover, natural in science that in this narrow San Blas region of the isthmus, which was slowly upheaved ages and ages before the more northern region was produced, that volcanic action should be now entirely dead, and as to earthquakes having their origin in regions more or less remote, the pent-up forces under the crust of the earth seeking a vent would be found to demonstrate their energies, according to science, in the line of least resistance, instead of up through a narrow ridge of high mountains with deep ocean beds on either side. It would appear, therefore, from all the considerations adduced, that we are entitled to expect entire safety for a tunnel pierced through the San Blas Cordillera.

It has been suggested by some of the friends of this route that the canal ought not to be taken into the Bayano river at all, but to make a separate cut for it along the valley of the river into the bay of Panama, with the object of avoiding the continual filling up of the deepened river and bar at its mouth by the material brought down from its head waters. That is merely a question of choice based upon cost; the bottom of this river is largely mud and easily excavated. It would cost about five million dollars extra to cut the canal outside of the river and make a proper mouth for it in the bay. The interest on this sum at four per cent. would represent an annual sum of $200,000. For half this sum per annum the required depth in the six miles of the Bayano river could be constantly maintained.

Judge DALY : Can you give us some idea of the general cost before you conclude?

Major SHELBOURNE : I have estimated the exact cost of the tunnel, as near as may be, placing the liberal prices I have named upon it. The cost of the preliminary tunnel would amount to $4,928,000; the cost of the remaining or floor work in the tunnel, at $3 per cubic yard, comes to $62,183,145, making about $67,000,000, assuming the width to be 100 feet and the height 168 feet for the whole tunnel. In addition to the tunnel there would be 17 miles of open-cut excavation, about one-half of which being of very small elevation the cutting would be light. You will observe, from the fact that no borings have been made to determine the depth through the soil to the rock, and no survey of an actual location of this line having been made, the character and depth of the open cutting at every particular point cannot now be given ; but a general estimate, coming within a fair approximation, can be attained. I should say that for four miles of this work a half million dollars per mile would be a liberal estimate ; for five miles of the remainder one million dollars per mile, and for the last eight miles a million and a half per mile would cover the whole cost, making the open cut work, outside of the tunnel, amount to $19,000,000. If two million dollars are allowed for the tide-lock on the Pacific and for other minor works of artificial construction, there would still remain twelve million dollars for general administration and contingencies to bring the total cost of a canal on this route up to 100 million dollars.

Judge DALY : What was the estimated cost by way of Nicaragua ?

Major SHELBOURNE : As estimated by Mr. Menocal, it was altogether, about $66,000,000. But that was by placing a very inadequate estimate upon the work. If the prices for two items alone—the open-cut rock excavation and the submarine rock excavation—are brought up to correspond with the prices I have placed for the San Blas route, his estimates would at once be increased by the large sum of $31,000,000 ; that is, by estimating 14,677,386 cubic yards of open-cut rock at $3 instead of $1.25 and $1.50, as he has it, and by estimating the submarine rock at $12.50 per cubic yard, instead of $5, the price he has assigned. Without considering any other under-estimates except these two, and adding his usual percentage for contingencies, the cost of the Nicaragua route would mount up to $104,421,790.

It will be seen that the San Blas route is free entirely from the troublesome question of a large surface drainage and intersecting rivers. Cut through at one level, from tide-water to tide-water, it takes only the parallel valleys of the little Mamoni, near its mouth, and the still smaller Vercalagua, on the Atlantic side.

For access, this route admits of ship navigation to within five miles of the mouth of the tunnel on the Atlantic side, at the very outset of the work, and within seven miles of the tunnel on the Pacific side—permitting the unloading of machinery from shipboard within easy distance of the main excavation.

The whole work, with the progress being made elsewhere in rock excavation, could be executed probably in six and certainly within eight years. The preliminary tunnel could be completed in four years ; but, from the outset, the open-cut work could be in free progress, and the floor excavation downward from the preliminary tunnel could follow closely upon the advancing heading. While the exposure of the entire work on the Nicaragua route would limit the operations to the daytime, and the work be suspended for times at least during the wet season, from rains above and floods beneath, the tunnel excavation at San Blas could proceed the year round, both night and day. For this reason 21 millions of cubic yards of floor rock could be excavated under the roof of the San Blas tunnel in less running time than the 15 million cubic yards of exposed open-cut rock on the route through Nicaragua.

It remains only to speak of maintenance and cost of towage. The advocates of the Nicaragua scheme have assigned a sum of a million and a half to two million dollars per year for the maintenance and operation of a canal by that route. Its total length is more than six times as great as the route by San Blas, and because of its multitude of locks and other artificial constructions, and the fact that its promoters are not noted for excessive figures—if we take the larger sum as the approximate one, and reckon a pro rata expense for this natural, rock-walled passage at San Blas—there will be held of its income, each year, an advantage over the Nicaragua route of more than a million and a half to the credit of its dividends.

And we mark the towage at the same proportion—five dollars of every six saved to the vessel, or, with no difference to its owner, added to the profits of the scheme. Would you not say that in these last items alone it would be easy to determine a balance of reasons sufficient to move the money circles of the world to the route they should choose ?

I have thus presented the most important features of construction and advantage of the shortest of all possible routes through the isthmus, and I have long had the conviction that it will eventually share alike the earnest attention and favor of men of science and capital and commerce.

Judge Daly spoke of the address of Major Shelbourne as being a clear, precise and practical exposition of the subject, founded upon facts and free from speculation—a communication of great importance.—The meeting then adjourned.